Louisiana Water Resources Research Institute
Annual Technical Report
FY 2016

Introduction

This report presents a description of the activities of the Louisiana Water Resources Research Institute for the period of March 1, 2016 to February 28, 2017 under the direction of Dr. Frank Tsai. The Louisiana Water Resources Research Institute (LWRRI) is unique among academic research institutions in the state because it is federally mandated to perform a statewide function of promoting research, education and services in water resources. The federal mandate recognizes the ubiquitous involvement of water in environmental and societal issues, and the need for a focal point for coordination.

As a member of the National Institutes of Water Resources, LWRRI is one of a network of 54 institutes nationwide initially authorized by Congress in 1964 and has been re-authorized through the Water Resources Research Act of 1984, as amended in 1996 by P.L. 104-147. Under the Act, the institutes are to:

"1) plan, conduct, or otherwise arrange for competent research that fosters, (A) the entry of new research scientists into water resources fields, (B) the training and education of future water scientists, engineers, and technicians, (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (D) the dissemination of research results to water managers and the public.

2) cooperate closely with other colleges and universities in the State that have demonstrated capabilities for research, information dissemination and graduate training in order to develop a statewide program designed to resolve State and regional water and related land problems. Each institute shall also cooperate closely with other institutes and organizations in the region to increase the effectiveness of the institutes and for the purpose of promoting regional coordination."

The National Water Resources Institutes program establishes a broad mandate to pursue a comprehensive approach to water resource issues that are related to state and regional needs. Louisiana is the water state; no other state has so much of its cultural and economic life involved with water resource issues. The oil and gas industry, the chemical industry, port activities, tourism and fisheries are all dependent upon the existence of a deltaic landscape containing major rivers, extensive wetlands, numerous large shallow water bays, and large thick sequences of river sediments all adjacent to the Gulf of Mexico.

Louisiana has an abundance of water resources, and while reaping their benefits, faces complex and crucial water problems. Louisiana's present water resources must be effectively managed, and the quality of these resources must be responsibly protected. A fundamental necessity is to assure continued availability and usability of the state's water supply for future generations. Specifically, Louisiana faces five major issues that threaten the quality of the state's water supply, which are also subsets of the southeastern/island region priorities:

Nonpoint sources of pollution are estimated to account for approximately one-half of Louisiana's pollution. Because of the potential impact of this pollution and the need to mitigate its effects while maintaining the state's extensive agricultural base and coastal zones, continued research is needed in the area of nonpoint issues. Louisiana's regulatory agencies are addressing non-point source problems through the development of waste load allocation models, modeling of atmospheric pollutants deposition to water bodies, and total maximum daily load (TMDL) calculations. There are serious technical issues that still require resolution to insure that progress is made in solving the non-point source problem.

Louisiana's vast wetlands make up approximately 40% of the nation's wetlands. These areas are composed of very sensitive and often delicately balanced ecosystems which make them particularly vulnerable to contamination or destruction resulting both from human activities and from natural occurrences.

Understanding these threats and finding management alternatives for the state's unique wetland resources are priority issues needing attention.

Water resources planning and management are ever-present dilemmas for Louisiana. Severe flooding of urban and residential areas periodically causes economic loss and human suffering, yet solutions to flooding problems can be problems in themselves. Water supply issues have also recently a focus of concern. Despite the abundance of resources, several aquifers have been in perennial overdraft, including the Southern Hills aquifer system, the Chicot aquifer system, and Sparta aquifer. Louisiana passed its first legislation that restricts groundwater use in the past year. Water resources and environmental issues are intricately interconnected; therefore, changes in one aspect produce a corresponding responsive change in another. Further study is needed to understand these relationships.

Water quality protection, particularly of ground water resources, is an area of concern in Louisiana. Researchers are beginning to see contamination and salty water in drinking water supplies. Delineating aquifer recharge areas, understanding the impacts of industrial activities on water resources, evaluating nonpoint sources of pollution, and exploring protection alternatives are issues at the forefront.

Wastewater management has been a long-standing issue in Louisiana. The problem of wastewater management focuses primarily on rural and agricultural wastewater and the high costs for conventional types of wastewater treatment as found in the petrochemical industry.

The Institute is administratively housed in the College of Engineering and maintains working relationships with several research and teaching units at Louisiana State University. A Recent cooperative research project has been conducted with LSU Agricultural Center.

During this reporting period, LWRRI continued its work on the saltwater intrusion issue in the Capital Area groundwater system. The LWRRI director advised state agencies, conducted ongoing research on saltwater encroachment modeling and remediation designs, organized a water symposium, and presented research results at local, regional and national meetings. Details of this activity are presented below in the “Notable Achievements” section of the report.

Research Program Introduction

The primary goal of the Institute is to help prepare water professionals and policy makers in the State of Louisiana to meet present and future needs for reliable information concerning national, regional, and state water resources issues. The specific objectives of the Institute are to fund the development of critical water resources technology, to foster the training of students to be water resources scientists and engineers capable of solving present and future water resources problems, to disseminate research results and findings to the general public, and to provide technical assistance to governmental and industrial personnel and the citizens of Louisiana.

The priority research areas for the Institute in FY 2016 focused on selected research themes developed in conjunction with the advisory board. These themes corresponded to the major water resource areas affecting Louisiana described in the Introduction above. Projects selected were from a range of faculty with different academic backgrounds including hydrologist, environmental engineers and water resource engineers and scientists. Supporting research in these priority areas has increased the visibility of the Institute within the State.

The individual research projects are listed below.

Project 2016LA103B (Sherchan) Occurrence and Control of Naegleria fowleri in Groundwater Sources in Louisiana – Tulane University

Project 2016LA104B (Quirk) Assessing the Spatial Extent, Temporal Variability and Mechanisms of Inland Hypoxia in Louisiana Waters – LSU

Project 2016LA105B (Paudel) Economic Impacts of Groundwater Salinity in Louisiana Agriculture – LSU AgCenter

Project 2016LA106B (Deng) Satellite-assisted approach to adaptive water quality management of Lower Boeuf River – LSU

These projects include one project that focuses on biological sciences (2016LA103B) and three projects that focus on water quality (2016LA104B, 2016LA105B, and 2016LA106B).

Occurrence and Control of Naegleria fowleri in Groundwater Sources in Louisiana

Basic Information

Title:	Occurrence and Control of Naegleria fowleri in Groundwater Sources in Louisiana
Project Number:	2016LA103B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	LA-02
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, None
Descriptors:	None
Principal Investigators:	Samendra Sherchan, Jeffrey Wickliffe

Publications

There are no publications.

Problem and Research Objectives

Naegleria fowleri, also known as "the brain-eating amoeba", is a free living amoebae found naturally in hot springs and warm surface waters. *N. fowleri* can cause primary meningoencephalitis (PAM), a rare and fatal disease in children and young adults. In 2011, two people died of PAM caused by *N. fowleri* in DeSoto Parish and St. Bernard Parish, Louisiana. Both cases involved the use of a neti-pot. In 2013, there was second death in St. Bernard Parish (4-year old boy) caused by PAM and confirmed to be *N. fowleri* infection (Cope et. al., (2015). Testing conducted in 2013 by Louisiana Department of Health and Hospitals (DHH)/CDC in both St. Bernard and DeSoto found this amoeba in the treated distribution system water supply. To date, a total of 6 Louisiana's public water systems have tested positive for *N. fowleri* (Louisiana DHH; Bartrand et al., 2014). The occurrence of this protozoan pathogen *N. fowleri* in the treated water supplies in Louisiana causing three deaths is the basis of this research project. This pathogenic free-living amoeba grows in warm water and is fairly resistant to chlorine based disinfection (Miller et al., 2015). The goal of this study is to gain baseline knowledge of the occurrence and quantity of *N. fowleri* in non-disinfected small drinking water systems and individual household well water systems in Louisiana. Over 500,000 people depend on private wells for their drinking water in the State of Louisiana (Louisiana DHH). In addition, guidance for both utilities and the general public is needed to determine how to reduce exposure to this organism in groundwater sources in Louisiana.

The proposed project involves a field study to assess the occurrence and quantity of *Naegleria fowleri* in non-disinfected small drinking water systems and individual household well water systems in Louisiana. The data collected will be analyzed to assess environmental and other water quality factors that may be associated with the occurrence of *N. fowleri* in these groundwater supplies.

Methodology

Sample collection

Well water samples from private wells around Southeastern Louisiana will be collected. According to our research plan, approximately 80 to 100 private well water samples are expected in this study (Now we have collected 19 private well water samples). For each site, two types of water samples were collected and they were pre- and post-flush water samples. Two-liter pre-flush water samples were collected in sterile 1-liter plastic containers and kept on ice immediately. The post-flush samples were collected after three minutes' flush and two-liter water samples were then collected and kept on ice. A YSI Pro2030 meter (YSI incorporated, OH) was used to measure *in-situ* dissolved oxygen, temperature, salinity, specific conductance, pH.

DNA extraction

On the day of sample arrival, 1000 ml from each sample were filtered through a 0.45 µm-pore-size membrane filter (Thermo Fisher Scientific, Waltham, MA) under vacuum. After filtration, sterile forceps were used to aseptically fold each of the membrane filters and placed in separate Whirl-Pak™ bags and stored at -20°C until the DNA extraction. Genomic DNA was isolated from membrane filters using the PowerSoil DNA Isolation Kit (Mo Bio Laboratories, Inc., Carlsbad, CA) according to the manufacturer's instructions. To maximize DNA extraction efficiency, membrane filters were cut into small pieces with sterile scissors and the DNA was quantified with a NanoDrop ND-2000 UV spectrophotometer (Thermo Scientific, Wilmington, USA). The DNA samples were stored at -20°C prior to use.

Enumeration of fecal coliform, E.coil and enterococci

Fecal-indicator bacteria were measured by IDDEX method within the required time frame following sample collection. Undiluted water samples was each mixed with reagent and placed in a Quantitray/2000 according to the manufacturer's instructions (Colilert and Enterolert product insert; IDEXX Laboratories). The Colilert test kit was used for measuring total coliform bacteria and *E. coli*. An Enterolert test kit was employed for measuring enterococci (e.g. *E. faecium* and *E. faecalis*). Quantitray/2000 was sealed using Quanti-Tray Sealer and incubated at 37˚C for 24 hours (41°C for enterococci). After incubation, the wells with having a bright yellow color were quantified as positive for total coliforms for the Colilert test. The wells that fluoresced under U.V. light at 366 nm were quantified as positive for *E. coli*. For the Enterolert test, the wells that fluoresced under U.V. light at 366 nm were quantified as positive for enterococci. The number of positive wells was compared to the manufacturer-provided MPN table to enumerate fecal coliform and enterococci in terms of MPN/100 ml.

Quantitative PCR assays

Quantitative polymerase chain reaction (PCR) assays targeting *E. coli*, Enterococcus, *N. fowleri* and *Legionella* were performed using the Applied Biosystems StepOne Real-Time PCR system (Applied Biosystems, NY). Here, the reaction mixture (15 µl) contained 1x PerfeCTa qCPR ToughMix (Quanta Biosciences, Beverly, MA), 0.2 µM of each primer, and 2.5 µl of the template DNA. QPCR reactions for *N. fowleri* were performed in duplicate and amplification protocols consisted with a hold at 95°C for 3 min, followed by 45 cycles of 95°C 10s, 63°C 10 s (60°C 10 s for *E.coli*), and 72°C 10 s. QPCR reactions for Enterococcus were performed in duplicate and amplification protocols consisted with a hold at 95°C for 2 min, followed by 40 cycles of 95°C 15s, 60°C 60 s. Genomic DNA (*Naegleria fowleri* ATCC 30174D; Enterococcus ATCC; *Escherichia coli* ATCC 700926DQ) for each marker were used to produce calibration curve with concentrations spanning the range from 10 to 10^6 gene copies per reaction, with two replicates, was constructed. Duplicate no-template controls (NTC) were included in each run. The amplification efficiencies (AE) were calculated based on the equation: $AE= 10^{(-1/slope)} – 1$. This method detects viable organisms, including the trophozoite stage of *N. fowleri*. A summary of qPCR target organisms, primer/ probe name, and sequences are detailed in Table 1.

Table 1. Summary of qPCR assay conditions (Integrated DNA Technologies).

Target Organism	Primer or Probe Name	Sequence
	784F	5'-GTG TGA TAT CTA CCC GCT TCG C-3'
E. coli	866R	5'-AGA ACG GTT TGT GGT TAA TCA GGA-3'
	Ec807	5'-FAM -TCG GCA TCC GGT CAG TGG CAG T-TAMRA-3'
Enterococcus spp.	EnteroF1A	5'-GAG AAA TTC CAA ACG AAC TTG-3'
	EnteroR1	5'-CAG TGC TCT ACC TCC ATC ATT-3'

N. fowleri	NaeglF192	5'-GTG CTG AAA CCT AGC TAT TGT AAC TCA FT-3'
	NaeglR344	5'-CAC TAG AAA AAG CAA ACC TGA AAG G-3'
	NfowlP	5'- /5HEX/ATA GCA ATA/ ZEN/ TAT TCA GGG GAG CTG GGC/ 31ABkFQ/-3'

Principal Findings and Significance

The chemical and physical parameters of water samples were analyzed *in situ*. The average pH value ranged between 8.7 and 10.0. The values of electrical conductivity (EC) measured varying between 334.3 and 2660.0 mS, with the highest value found in well NF29 which locat on the west shore of Lake Pontchartrain. Similarly, water salinity ranged between 0.17 and 1.31 ppt, with the highest value found in well NF29. The water temperature was ranged from 17℃ to 39℃ with the highest temperature found at NF07 pre-flush. The unusual high temperature was probably because that water was collected from a water hose which laid on the ground under direct sunshine. The dissolved oxygen measured varying between 1.5 and 7.4 mg/L.

A total of 41 water samples were analyzed by using IDEXX method. The biological water quality of those samples was assessed by using fecal indicator bacteria (FIB) such as fecal coliform, *E. coli* and enterococci. Fecal coliform was present in 26 out of 41 water samples at levels ranging from 1 to 2450 CFU/100 ml. Under most circumstance, the counts of fecal coliform decreased after three minutes' flushing, the decreasing rate ranged from 18.9% to 100%. The fecal coliform counts didn't change after flushing at three private wells (NF06, 21 and 24) and the fecal coliform counts increased at two private wells (NF07 and 29). *E. coli* was only detected in three water samples at value levels ranging between 1 and 2 CFU/100 ml. *E. coli* was found in Pre- and Post-flush water samples collected from NF28 which is located on the west shore of Lake Pontchartrain. The *E. coli* counts did not change after three minutes' flushing at NF28. Enterococci were present in eight out of 23 water samples at levels ranging from 1 to 12 CFU/100 ml with the highest enterococcal concentration being observed for NF9 pre-flush water sample (Only 23 water samples were observed for Enterococci so far). Among the four private wells, Enterococci decreased after three minutes' flushing and the decreasing rates ranged from 68% to 100%.

Quantitative real-time PCR were performed on twenty-three water samples targeting *Naegleria fowleri*, *E. coli* and enterococci so far. *E. coli* was detected in 14 out of 23 water samples at value levels ranging between 60.4 and 90.5 GC/100 ml. More samples showed positive signals with *E. coli* indicated higher sensitivity of PCR based molecular method compare with culture based method. Enterococci were detected in seven out of 23 water samples at levels ranging between 9.5 and 117.5 GC/100 ml. We did not detect any positive for *N. fowleri*, more samples will be collected this year before submitting a final report.

Table 2 Analysis for chemical, physical and biological parameters on private-well water samples

Sample ID	T. Coli.	*E. coli*		Enterococci		Tm	DO	pH	Cond.	Salinity
	MPN	GC/100 ml	MPN	GC/100 ml	MPN	°C	mg/L		mS	ppt
NF01-1	<1	75.5	<1	/	<1	23.1	4.66	10.0	375	0.19

NF02 pre	<1	65.1	<1	117.5	<1	23.6	3.80	9.8	364	0.18
NF02 pos	<1	/	<1	/	<1	22.8	4.90	9.8	357	0.18
NF03 pre	2	/	<1	9.6	<1	25.7	4.88	9.5	396	0.19
NF03 pos	<1	68.6	<1	/	<1	24.1	5.62	9.6	385	0.19
NF04 sink	<1	60.4	<1	/	<1	23.6	4.13	9.3	516	0.26
NF04 pre	<1	/	<1	/	<1	23.6	4.63	9.4	518	0.26
NF04 pos	<1	69.8	<1	/	1	22.6	5.31	9.5	506	0.26
NF05 pos	<1	/	<1	/	<1	23.1	/	9.4	506	0.25
NF06 pre	1	61.0	<1	/	6.1	22.5	4.43	9.0	541	0.27
NF06 pos	1	/	<1	/	<1	21.7	2.85	9.0	524	0.27
NF07 pre	8.1	90.5	<1	/	<1	39.0	2.72	8.9	721	0.27
NF07 pos	19.3	/	<1	/	<1	23.7	5.03	8.8	547	0.27
NF8 out-pre	2450	/	<1	9.5	<1	20.8	1.51	9.5	533	0.28
NF8 out-pos	1986.3	/	<1	/	<1	21.2	2.20	9.6	537	0.28
NF8 in-pre	101.7	67.5	<1	/	<1	22.4	5.15	9.1	549	0.28
NF8 in-pos	44.8	88.5	<1	24.3	<1	20.2	5.74	9.3	522	0.28
NF9 out-pre	1413.6	79.9	<1	18.6	6.3	17.6	3.50	9.4	530	0.30
NF9 out-pos	727	/	<1	42.0	2	19.1	4.74	9.4	548	0.30
NF9 in-pre	866.4	63.7	2	/	12	20.5	4.83	9.4	565	0.30
NF9 in-pos	235.9	69.5	<1	/	1	19.7	5.58	9.5	543	0.30
NF10 pre	1732.9	75.0	<1	/	4.1	21.9	4.56	9.3	342	0.17
NF10 pos	920.8	71.5	<1	19.2	1	20.8	3.91	9.2	334	0.17
NF 21 Pre	5.2		<1			19.1	3.24	9.0	1586	0.91
NF 21 Pos	5.2		<1			19.3	2.4	9.0	1588	0.91
NF 22 Pos	4.1		<1			22.5	3.21	9.0	1364	0.72
NF 23 Pre	1		<1			17.0	4.25	9.0	1499	0.90
NF 23 Pos	<1		<1			20.9	2.82	9.0	1635	0.90
NF23 filtered	<1		<1			21.1	2.33	9.0	1640	0.90
NF 24 Pre	1		<1			20.4	3.78	8.9	1824	1.02
NF 24 Pos	1		<1			22.5	2.66	8.9	1898	1.02
NF 25 Pre	2		<1			21.2	2.82	8.9	1829	1.01
NF 25 Pos	<1		<1			20.7	2.68	8.8	1794	1.00
NF 26 Pre	<1		<1			22.5	6.38	9.0	1877	1.00
NF 26 Post	<1		<1			22.8	7.44	8.9	1886	1.00
NF 27 Pre	<1		<1			23.4	5.94	8.9	1692	0.88
NF 27 Post	<1		<1			23.3	7.1	8.9	1685	0.88
NF 28 Pre	53.8		1			25.5	6.95	8.9	2027	1.02
NF 28 Post	39.3		1			22.7	7.4	8.8	2283	1.23
NF 29 Pre	1		<1			27.4	4.5	8.7	2660	1.30
NF 29 Post	79.8		<1			26.7	2.5	8.8	2619	1.31
Max	2450.0	90.5	2.0	117.5	12.0	39.0	7.4	10.0	2660.0	1.31
Min	1.0	60.4	1.0	9.5	1.0	17.0	1.5	8.7	334.3	0.17
Average	411.7	71.9	1.3	34.4	4.2	22.5	4.3	9.2	1088.9	0.58

Assessing the Spatial Extent, Temporal Variability and Mechanisms of Inland Hypoxia in Louisiana Waters

Basic Information

Title:	Assessing the Spatial Extent, Temporal Variability and Mechanisms of Inland Hypoxia in Louisiana Waters
Project Number:	2016LA104B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	LA-06
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Nutrients
Descriptors:	None
Principal Investigators:	Tracy Quirk, Kanchan Maiti

Publications

1. Candilora, K., Quirk, T., Maiti, K. 2017. “Oxygen Dynamics in Low Flow Bayous Across Southern Louisiana” Louisiana State University, Discover Day, April 4, 2017
2. Quirk, T., Maiti, K, Candilora, K. in prep. Dissolved oxygen and oxygen consumption dynamics in low flow bayous of southeast Louisiana.

Problem and Research Objectives

Streams and bayous are abundant surface water resources in south Louisiana. These streams and bayous form the link between larger rivers and lakes and coastal waters, providing water for public supply, industrial and agricultural use, and natural ecosystems. However, the quality of the water in small waterways may be impaired associated with excess nutrients, organic and inorganic substances such as heavy metals associated with surrounding land-use. Depending on whether watershed land-use is primarily agricultural or forested, both nutrient and oxygen dynamics can be altered including the timing and magnitude of low dissolved oxygen concentrations and hypoxia, where oxygen concentrations are less than 2 mg/L.

Hypoxic events in low-lying slow flowing channels may occur naturally; however, extensive river management and basin-wide land-use changes have increased their frequency and impact (Whitworth et al. 2012). In low-energy channels of the Atchafalaya River Basin, chronic hypoxic conditions are common when water temperature and river stage are high (Sabo et al. 1999). While low dissolved oxygen is common in nutrient rich shallow water when organic matter is concentrated by receding waters and biological oxygen demand is fueled by warm temperatures (Tramer 1977), Sabo et al. (1999) found chronic hypoxia in the spring and early summer when the river stage was high and phytoplankton densities and percent oxygen saturation were low. It was surmised that decomposition of organic matter and biological consumption of oxygen was causing the chronic hypoxia, although this was not tested. No relationship between low dissolved oxygen and total organic carbon was observed. Unfortunately, dissolved organic carbon (DOC) concentration was not measured and hence it cannot be determined whether microbial respiration of DOC plays an important role. For channels seasonally inundated by floodwaters, DOC is leached from plant litter, or derived from soils, living plants, algae and microorganisms (Meyer et al. 1990). The variation in sources of DOC and biological oxygen demand across low-flow streams and bayous across Louisiana is unknown. In addition, the seasonality and mechanisms of hypoxia may differ from backwater forested channels to more eutrophic channels surrounded by agriculture.

Surrounding land-use may play a key role in aquatic oxygen dynamics. A comparison of nutrient-poor forested and a nutrient-rich open stream in the Oria watershed in Spain illustrated strong diel fluctuations in dissolved oxygen and periodic hypoxia in the open channel, while the low nutrient forested stream experienced steady oxygen concentrations above 5 mg/L (Sabater et al. 2000). In forested systems, oxygen dynamics may be less influenced by diel changes in respiration of microorganisms decomposing algal biomass than in less light-limited open channels. Differences in oxygen dynamics may be directly related to the timing and source of nutrient and carbon input. In forested streams, much of the DOC is leached from plant litter in the form of fallen leaves (Hladyz et al. 2011). The impact on oxygen dynamics will depend on the timing and water temperature during and after litterfall. A period of leaching and physical breakdown when microbial activity is low in the fall and winter may reduce the lability of C in the spring and summer when microbial activity may be greatest. In contrast, in slow moving moderately eutrophic open bayous surrounded by agricultural land, nutrient enrichment can stimulate the growth of epiphytic and/or filamentous algae. Adverse effects of nutrient enrichment include a reduction in aeration of the water column from the loss of submerged plant photosynthesis and an increased uptake of oxygen through decomposition of surface aquatics. The water becomes hypoxic to anoxic, decomposition continues anaerobically, and plants and animals requiring oxygen cannot survive.

The objectives of this research were threefold: (1) determine the spatial extent of inland hypoxia in low-flow stream and bayous in south Louisiana in the summer; (2) examine temporal dynamics of dissolved oxygen conditions in two waterways, one with bottomland forested and the other with agricultural watershed land-use; and (3) examine possible mechanisms leading to hypoxia including biological oxygen demand, sediment organic matter content, and total and dissolved organic carbon concentrations in the two systems. Additional important co-varying parameters (e.g., temperature, pH, turbidity, flow) were also examined to inform predictive models of low oxygen conditions.

Methodology

Objective 1: *Spatial Extent of Inland Hypoxia*

To assess oxygen conditions in bayous of southeast Louisiana in the Mississippi and Atchafalaya basins, we conducted surveys of dissolved oxygen (DO), pH, temperature, conductivity, depth and width of stream, and vegetation along surveyed 8 major bayous, including the Amite River Diversion Canal, Bayou Fusil, Bayou Gross Tete, Bayou Plaquemine, Blind River, Choctaw Bayou, Old Parish Canal, and Petite Amite River (**Figure 1**). A minimum of three and up to nine random survey points approximately 1 km apart were established in each bayou. Data was collected every 50 cm from the surface to the bottom of the water column. Water column parameters were collected using an YSI Professional Plus multi-parameter probe. Instruments were calibrated prior to each sampling trip. Additional data including drainage basin size, surrounding land-use, and predominate vegetation species and form (e.g., emergent, submerged, surface) and percent cover was collected for each sample location.

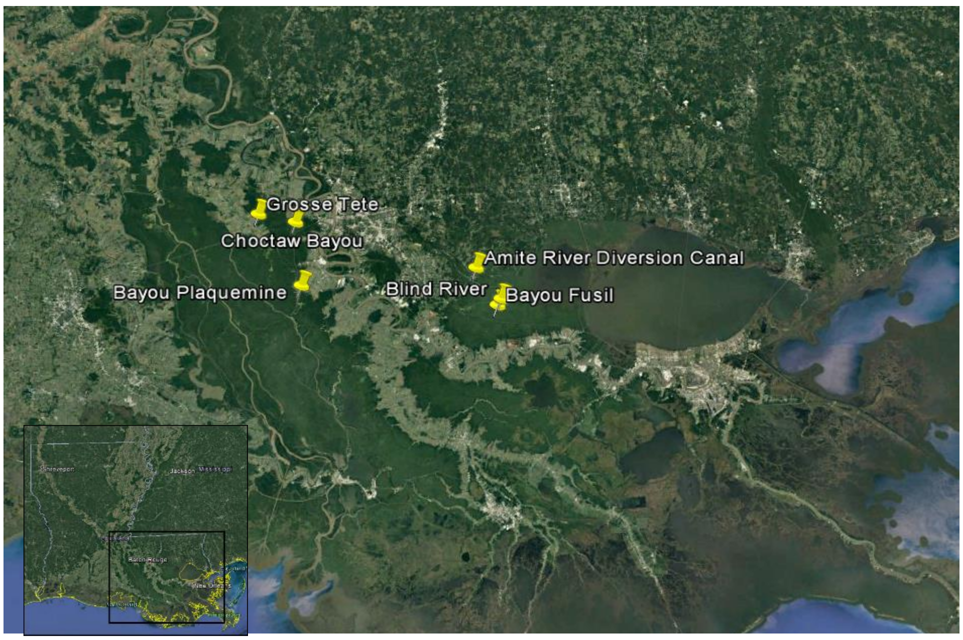

Figure 1. Survey locations in southeast Louisiana, USA.

Objective 2: *Temporal Dynamics of Dissolved Oxygen*

Based on the above survey, we selected two locations with differing watershed land-use where continuous dissolved oxygen is being monitored over a one year period. Old Parish Canal is a part of the Atchafalaya Basin and is a forested backwater bayou. The second location is in Bayou Grosse Tete, surrounded by predominantly light residential and agricultural land-use. Continuous oxygen sensors were placed approximately 10 cm above the bottom of the stream to characterize bottom-water hypoxia over a one year period. The sensor was attached to an anchor with a corkscrew head to stabilize in the sediment.

Objective 3: *Mechanisms Leading to Hypoxic Conditions*

To examine the mechanisms involved in the formation and maintenance of hypoxic conditions in two contrasting stream types, laboratory incubations were conducted to measure biological oxygen demand and to isolate sources of carbon fueling oxygen consumption. At each of the two locations in *Objective 2*, sediment cores and water samples were collected during time periods when oxygen concentrations are less than 2 mg/L. In October 2016, we collected three sediment cores and approximately 60 L of creek water to establish three experimental units for which oxygen consumption was measured. The three units were: filtered water overlying sediment (C1), unfiltered water samples (C2) and filtered water samples (C3; **Figure 2**). Samples were incubated in air-tight core tubes or bottles at in situ temperature, and DO was recorded over time, approximately every 2 – 3 hrs until dissolved oxygen concentration dropped to zero. The oxygen consumption rates were calculated using the change in DO between sampling times. Dissolved oxygen concentration was measured using a high precision clark-type oxygen microelectrode with a detection limit of 0.05 µM (0.002 mg/L). This experiment allowed us to calculate the individual role of sediment, dissolved organic matter and suspended organic matter in consuming oxygen leading to formation of hypoxia (as per mass balance equations shown in **Figure 2**), as well as the total oxygen consumption rates at these two locations.

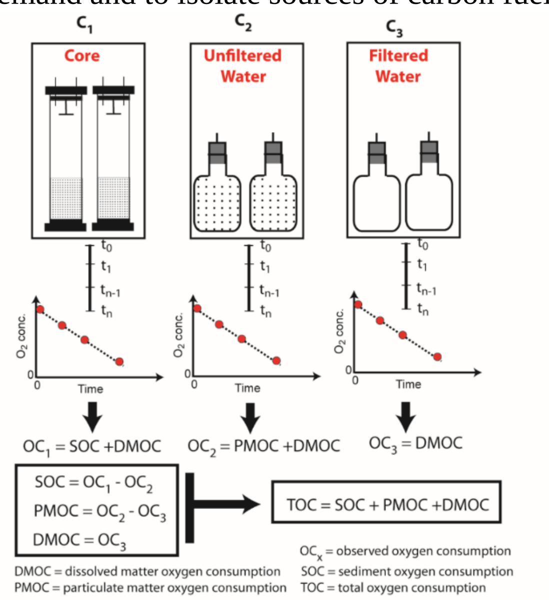

Figure 2. Schematics of oxygen consumption incubation experiment

Principal Findings and Significance

<u>*Hypoxia Survey*</u>

Seven of the eight bayous surveyed were surrounded by bottomland hardwood forest **(Table 1)**. Emergent vegetation on the sides of the stream channels ranging from an average of 6 – 29% cover of the channel area. Stream widths ranged from an average of 5 to 33 m and depths ranged from less than 1 m to an average of 4.5 m (Table 1). Temperatures were similar among bayous even when comparing streams surveyed in August to those surveyed in October, all of which averaged around 26°C. pH varied slightly and ranged from an average of 6.7 to 7.5.

Table 1. Characteristics of bayous surveyed for dissolved oxygen. Values are means ± standard errors across survey locations and depths.

			Vegetation cover (%)							
Location	**Date Surveyed**	**Shoreline Vegetation**	**Emergent**	**Surface**	**Submerged**	**Width of Channel (m)**	**Depth of Channel (m)**	**Temp ©**	**Cond (uS/cm)**	**pH**
Amite River Diversion Canal	9/16/2016	BHW	17 ± 4	16 ± 4	2.6 ± 0.8	18 ± 2	2.5 ± 0.2	27.64 ± 0.03	98.3 ± 0.2	7.0 ± 0.1
Bayou Fusil	10/2/2016	BHW	28 ± 4	0	0	14 ± 1	1.7 ± 0.1	25.28 ± 0.27	169.2 ± 2.6	7.1 ± 0.1
Bayou Gross Tete	9/9/2016	Forested/residential	29 ± 3	0	0	19 ± 1	4.0 ± 0.1	26.72 ± 0.05	140.7 ± 3.2	6.8 ± 0.1
Bayou Plaquemine	8/24/2016	BHW	7 ± 2	0	0	31 ± 2	3.0 ± 0.1	26.51 ± 0.05	76.7 ± 1.7	6.7 ± 0.1
Blind River	10/2/2016	BHW	24 ± 3	0	0	33 ± 3	4.5 ± 0.5	26.61 ± 0.12	156.2 ± 0.3	6.9 ± 0.1
Choctaw Bayou	9/18/2016	BHW	6 ± 1	0	0	14 ± 1	0.9 ± 0.1	26.66 ± 0.91	230.0 ± 28.9	7.5 ± 0.1
Old Parish Canal	9/18/2016	BHW	10 ± 0	0	0	5 ± 1	1.4 ± 0.1	27.43 ± 0.03	227.1 ± 1.8	7.5 ± 0.1
Petite Amite River	9/16/2016	BHW	9 ± 1	3 ± 1	0	21 ± 1	3.7 ± 0.2	27.90 ± 0.03	101.9 ± 0.8	6.8 ± 0.1

Oxygen concentrations ranged from 0.1 to 5.2 mg/L at the surface (**Figure 3**). Bayous with relatively high surface DO had DO concentration that declined with depth, all to below hypoxic conditions below 1.5 m depth. Bayous with low DO at the surface tended to have a relatively constant low DO with increasing depth.

The two bayous with surface oxygen concentrations above 3 mg/L were surveyed in October and thus seasonal changes may have influenced the difference between those bayous and the others in the survey. Continuous oxygen measurements will shed light on temporal changes in near-bottom oxygen concentration.

Temporal Dynamics of Dissolved Oxygen

Oxygen concentrations show more extreme variation in the forested Choctaw Bayou (CT) as compared to Grosse Tete (GT) (**Figure 4**). Diurnal fluctuations in DO associated with photosynthesis + respiration during the day and respiration only at night, as well as seasonal fluctuations related to temperature and biological activity are expected. In the CT site, water level fluctuations exposed the sensor at low water from October through December. When water levels rose, oxygen dynamics ranged from close to 0 to over 8 mg/L.

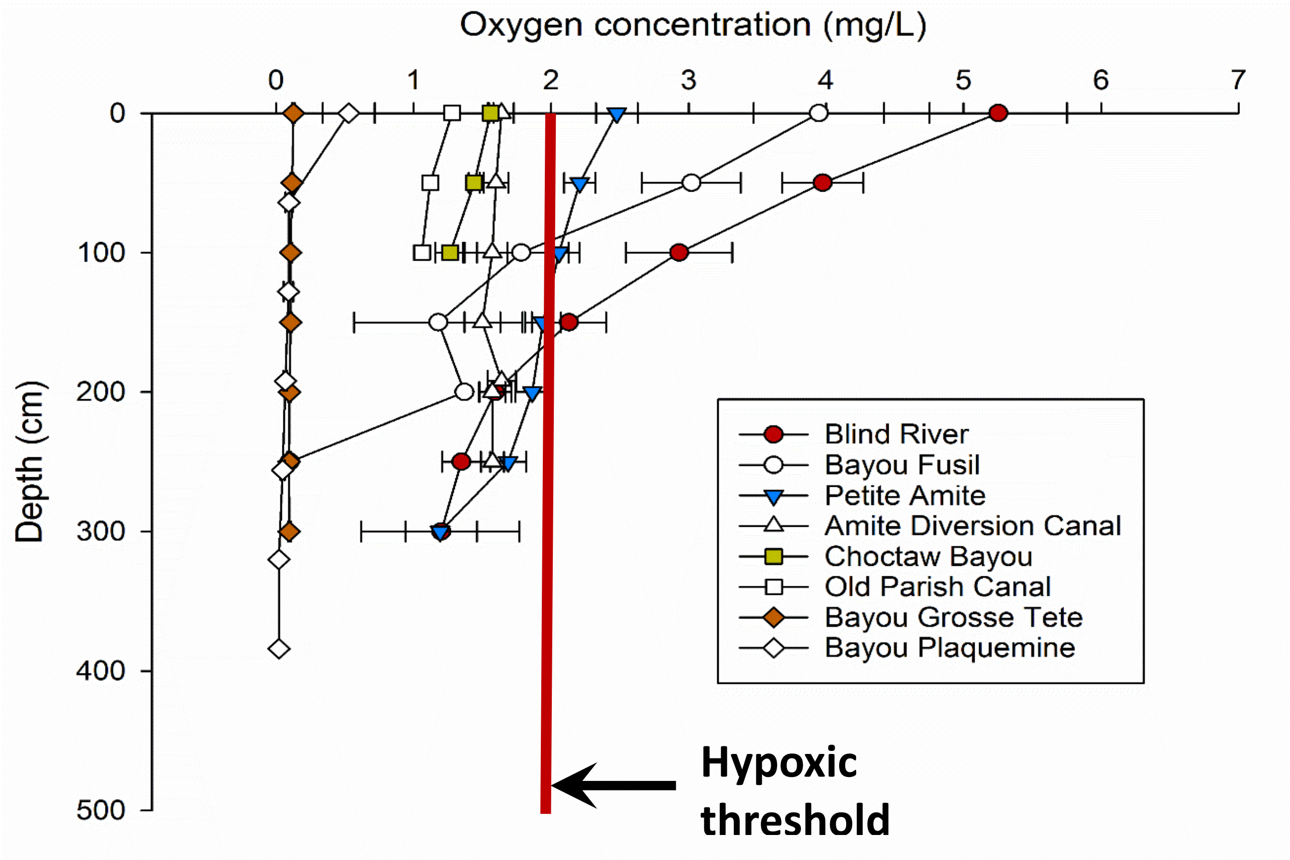

Figure 3. Dissolved oxygen concentrations in bayous of southern Louisiana August – October 2016.

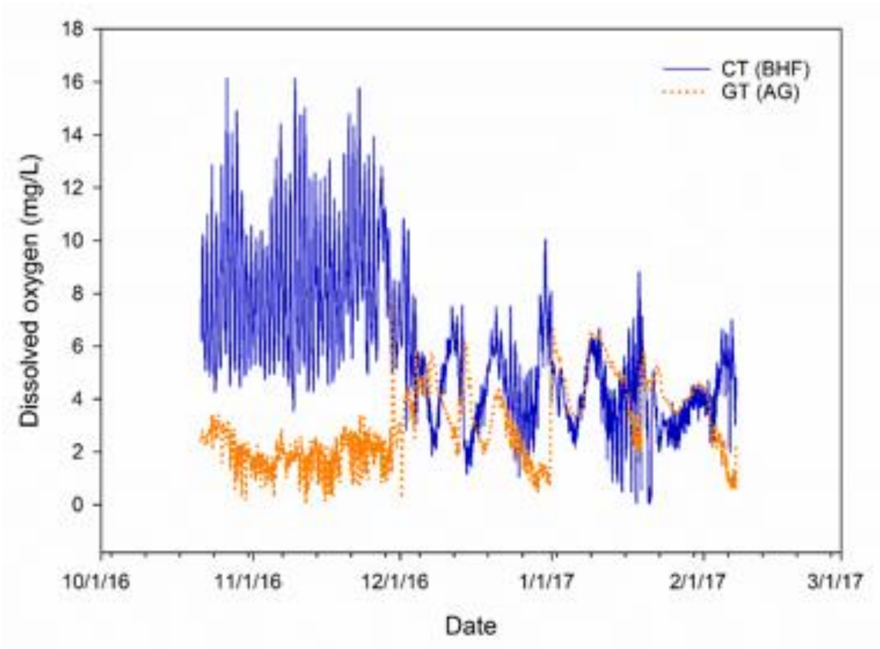

Figure 4. Initial oxygen concentrations in the forested Choctaw Bayou (CT) and in the agricultural Grosse Tete (GT) Bayou.

In GT, oxygen concentrations were low < 4 mg/L until December, after which there were greater fluctuations in DO with higher concentrations overall, likely associated with lower temperatures and higher. DO concentrations are continuing to be monitored throughout the summer and into the fall of 2017.

Oxygen consumption

Sediment and water (filtered and unfiltered) were oxygenated and then incubated in the lab at in-situ temperatures for measurement of oxygen consumption. All samples had initial DO concentrations around 10 mg/L, which declined linearly over time. In the sediment samples, DO tended to decline at a faster rate with oxygen concentrations generally reaching close to 0 mg/L by 1200 hrs after the start of the experiment (**Figures 5 and 6**). DO decline was slower in both filtered and unfiltered water. Filtering water had little effect on DO consumption rate, thus respiration may be occurring by smaller organisms. Most of the oxygen consumption occurred in the sediments (~50 mg/m^2/hr) from both bayous (**Figure 7**). There was no difference between bayous in the location and magnitude of oxygen consumption (**Figure 7**).

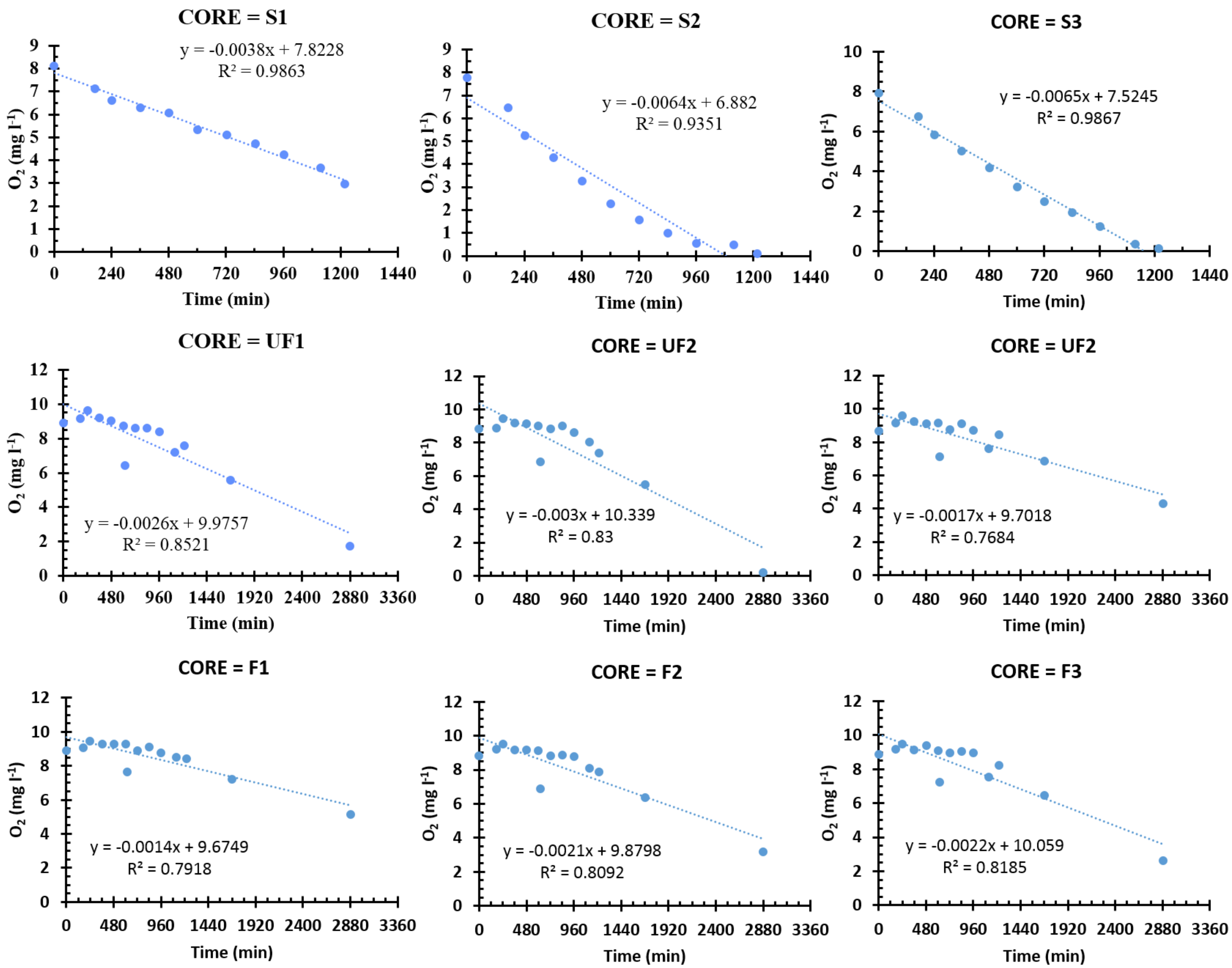

Figure 5. Time series oxygen concentrations in sediment, and unfiltered and filtered water from Choctaw Bayou.

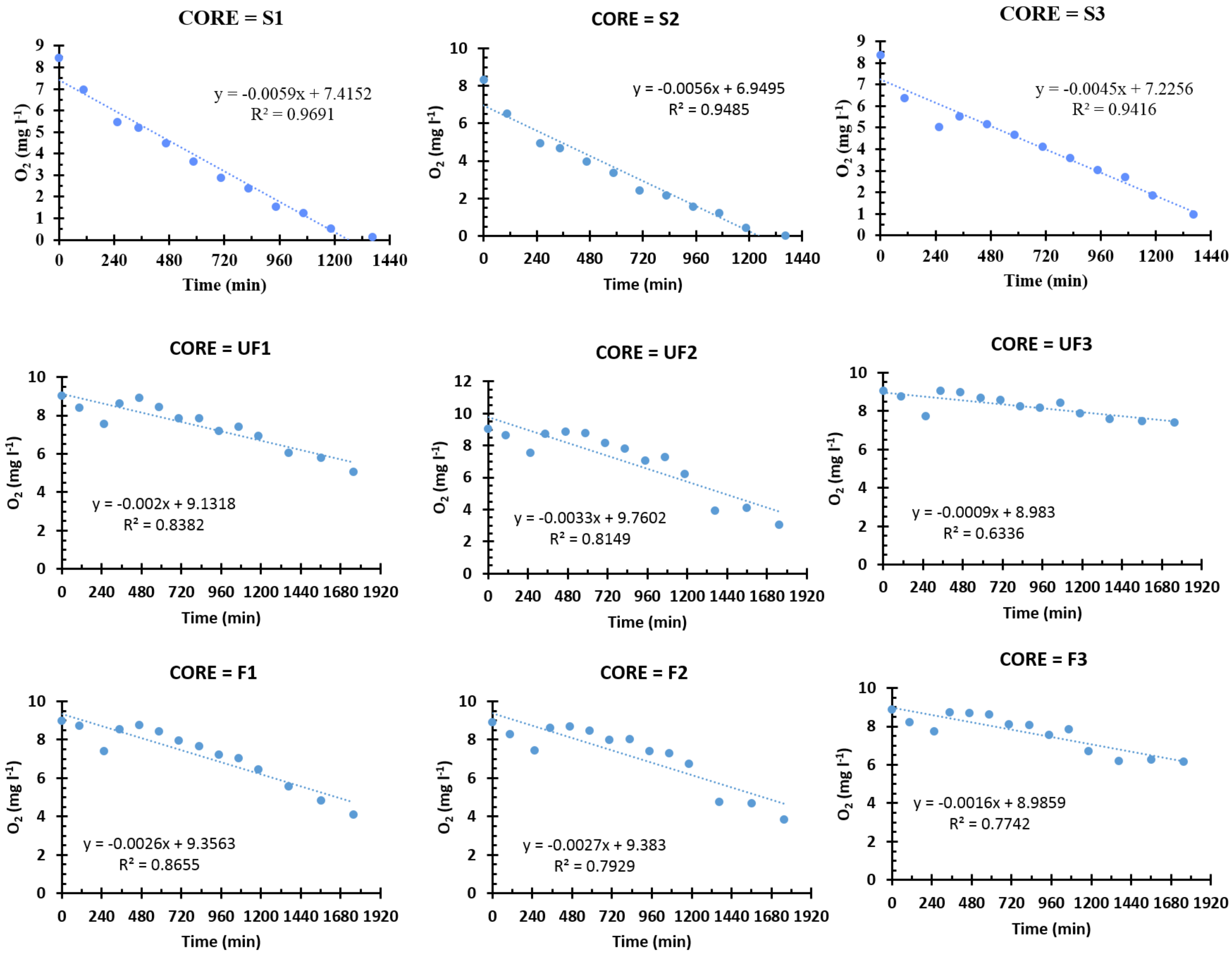

Figure 6. Time series oxygen concentrations in sediment, and unfiltered and filtered water from Gross Tete.

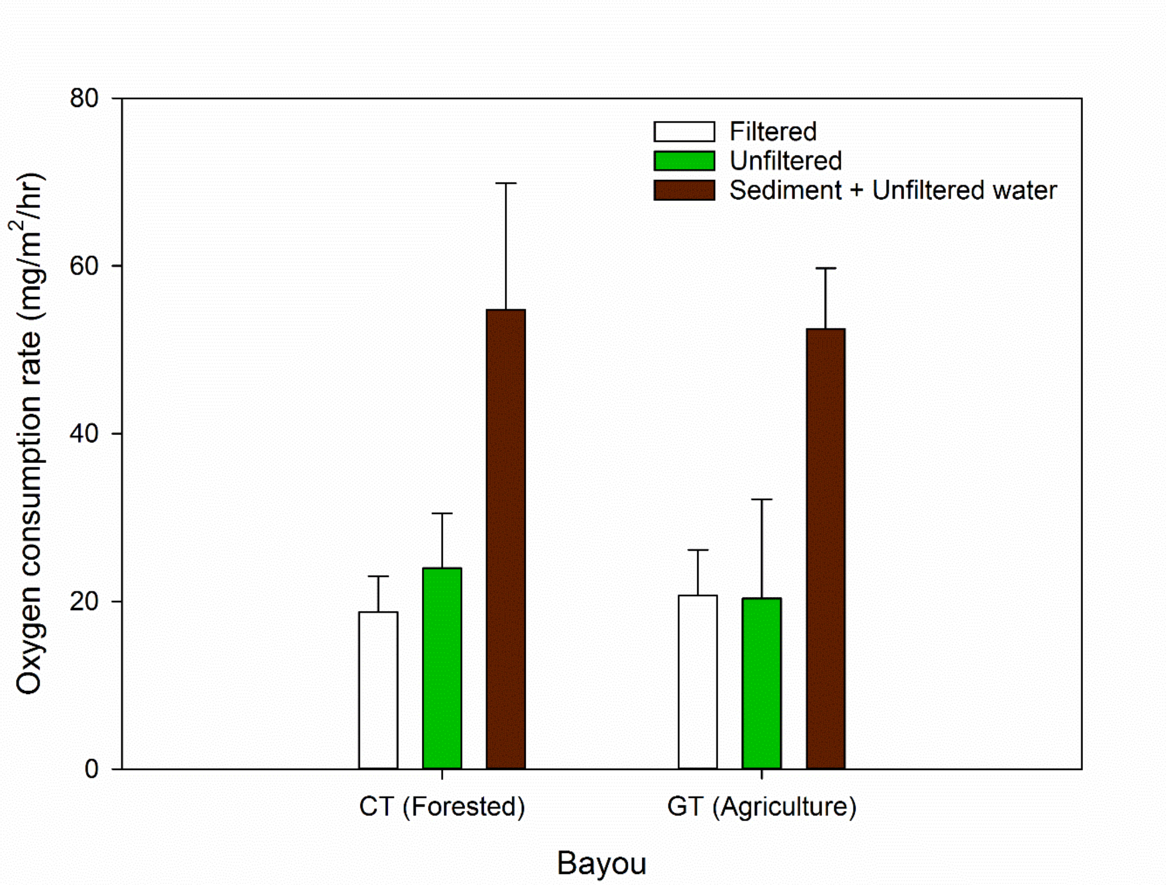

Figure 7. Average DO consumption rate across samples in two bayous surrounded by different land-use.

Summary and Significance

Five of the eight bayous had hypoxic conditions throughout the vertical depth profile. Three of the eight had DO concentrations between 2 and 6 mg/L within the top 1 m depth. Most of the DO consumption was occurring in the sediments not the water column. Diurnal fluctuations in DO were apparent from continuous oxygen sensor data. Maximum DO concentrations were greater in the bayou surrounded by bottomland hardwood forest than the bayou surrounded by agriculture. Under controlled conditions, oxygen consumption rates were similar among the two bayous, and therefore, differences in other limiting factors or photosynthesis likely play a role in influencing differences in temporal DO dynamics. Small bayous provide important habitat for fish and other species and low oxygen conditions that can develop in the summer can limit aquatic organism distribution and survivorship.

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Economic Impacts of Groundwater Salinity in Louisiana Agriculture

Basic Information

Title:	Economic Impacts of Groundwater Salinity in Louisiana Agriculture
Project Number:	2016LA105B
Start Date:	3/1/2016
End Date:	2/28/2017
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Congressional District:	LA-06
Research Category:	Water Quality
Focus Category:	Agriculture, Economics, Irrigation
Descriptors:	None
Principal Investigators:	Krishna P. Paudel

Publications

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2. Paudel, Krishna; Huizhen Niu; Dependra Bhatta; Frank Tsai, 2017, Using GIS to calculate crop area and water use in Louisiana 2004-2016, 2017 Southern Central Arc User Group and Louisiana Remote Sensing/GIS Conference, Baton Rouge, Louisiana, March 27-31.
3. Paudel, Krishna; Huizhen Niu; Dependra Bhatta; Frank Tsai, 2017, Evolution of irrigated crop areas and water use in Louisiana 2004 2016, 11th Annual Louisiana Groundwater, Surface Water, and Water Resources Symposium, Baton Rouge, Louisiana, April 11-12.
4. Karakullukcu; Ramazan, Dependra Bhatta; Frank Tsai; Krishna Paudel 2017 Construction of the Mississippi River Alluvial Aquifer, Northeast Louisiana, 11th Annual Louisiana Groundwater, Surface Water, and Water Resources Symposium, Baton Rouge, Louisiana April 11-12.

Problem and Research Objectives

About 800 million hectares of land have soil salinity issue across the globe (6% of total land area of the world with 4 dS/m or 40 mM sodium chloride in soil). Thirty two million hectares of 1,500 million hectares farmed by dryland agriculture are affected by secondary salinity while 45 million hectares of 230 million hectares of irrigated land are affected. Salinity due to agricultural practices is the second largest source of land degradation (FAO 2003). Since crops get adversely affected by soil salinity, it poses a threat for agriculture sustainability, thus, impacting the social, economic and environmental values (Williams 1999).

According to United States Department of Agriculture (USDA), roughly 56 million acres (7.6%) of all the U.S. cropland and pastureland were irrigated in 2012. The USDA survey-2010 has reported that of the total fresh groundwater withdrawals (76,000 Mgal/day), irrigation accounted for 65 percent of the total use. Nearly, all groundwater withdrawals (96 percent) were from freshwater. Moreover, in the U.S., soil salinity has impacted nearly 24 million hectares.

In Louisiana, several coastal and inland aquifers are showing the initial level of salinity. Soil salinity gets accumulated in agricultural land by the use saline water for irrigation followed by high evapotranspiration and low precipitation.

Soybeans and feed grain production contributes significantly to Louisiana's economy. Most soybeans in Louisiana are produced in the Northeastern part of the state. Northeast Mississippi River Valley Alluvial Aquifer (MRVAA) parishes shared 65% of total soybean cultivated area of Louisiana in 2016 (FSA, 2016). Average soybean yield in 2014 was 57 bushels per acre and soybeans were produced in 1.39 million acres by 2509 producers in that year. The total economic contribution of soybean to the state is $1.2 billion. The region also produces significant amount of other grain crops such as corn, wheat and sorghum. The total value of these feed grain crops in the state are $396.4 million ($74.6 million for wheat, $37.9 million for sorghum, $298.1 million for corn).

In a growing season from land preparation till harvesting, soybean requires 20-25 inch water per acre. Given that irrigation hedges the risk associated with an uncertain rainfall pattern, increasing numbers of farmers in the region are irrigating soybeans and other feed grains (except sorghum). In addition to hedge against the climate risk, farmers have been realizing significant increase in net revenue from irrigation even during normal years.

Water in MRVAA has recently shown an increased salt concentration level. At the present Louisiana farmers can withdraw as much water as they need for irrigation. With the advent of polypipe, electric submersible pump, and laser leveling, the cost of irrigating crop fields has been substantially reduced. It is our observation that farmers are withdrawing as much water as needed to irrigate during the critical crop growth period of crops if they perceive that there is not enough rainfall since the last time they have irrigated the field.

Expansion of irrigated area and dependence on groundwater for irrigation in these crop growing areas have put enormous pressure on the MRVAA. In fact, farmers have been noticing higher concentration of salt in groundwater used for irrigation purpose. If continuous withdrawal of water is to be a norm, many fields are likely to have irrigation salinity problem that would result in build-up of salt in soil surface. Given groundwater is an open access resources, there is likely that social optimal may not be the private optimal withdraw. Further, without consideration of extractions by all users, there is likelihood that stock externality would persist. This means an individual farmer would withdraw more than necessary amount of groundwater.

This excessive withdrawal of water and resulting salinity problem may have far reaching adverse effects. Given agriculture is the mainstay of economy in the region, the region would suffer tremendous negative economic and social impacts. Benign impacts from soil salinity problem could be just changing the cropping system but at the extreme the whole region may be uncultivable in future. This would be clearly detrimental to the region and Louisiana Agriculture.

To overcome irrigation salinity, several measures can be taken. First, a comprehensive land water management plans should be developed. This means assessing all available water from groundwater and surface water in the region. Additionally, applying only the right amount of irrigation water that is sufficient for crops demand should be considered. Other land management practice that can help to reduce the adverse effects from soil salinity are using good soil management, avoiding deep tillage, and adopting crop rotation measure. Similarly engineering measure such as subsurface tile drainage may help to capture water below the plant roots.

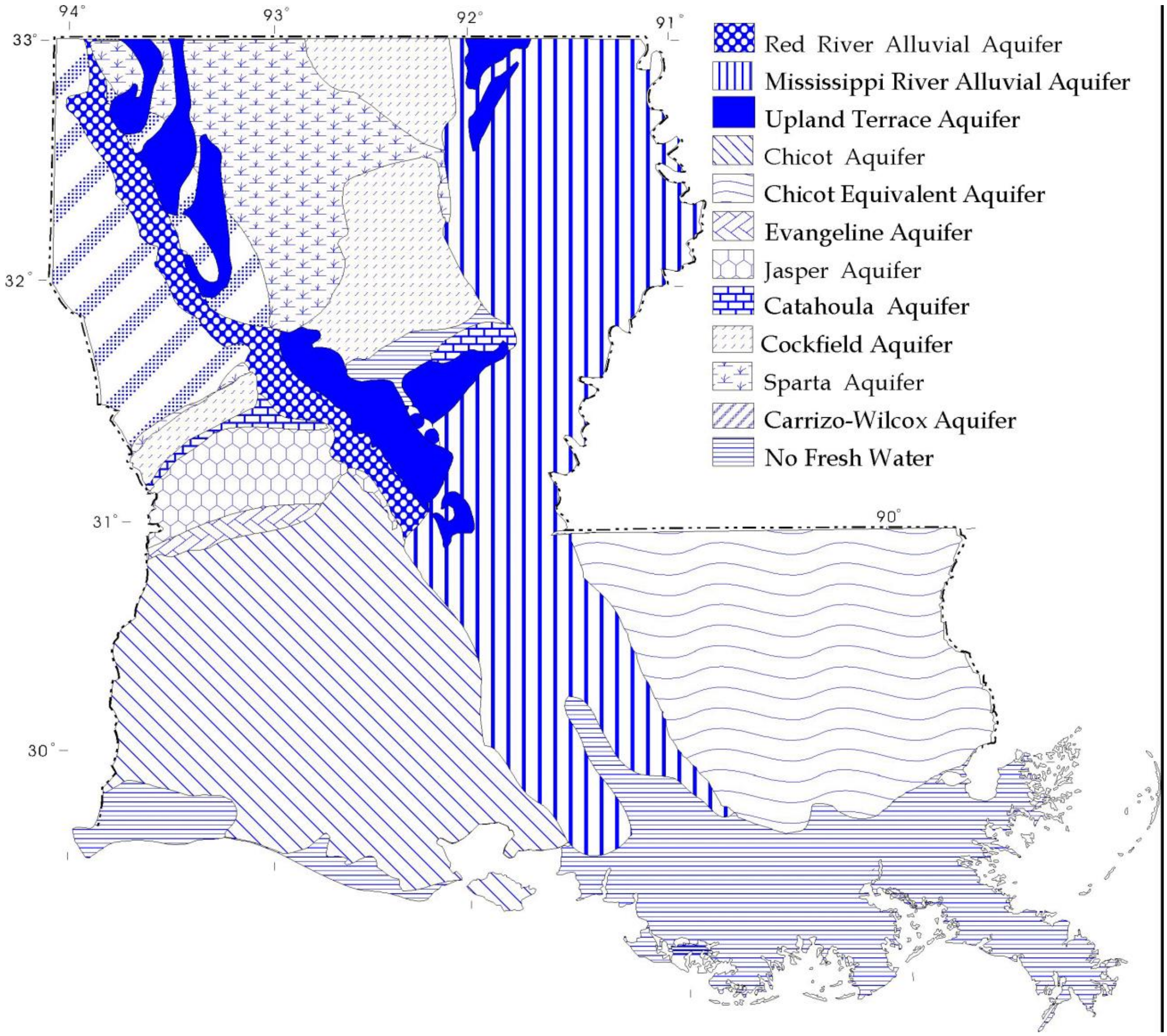

Figure 1. Louisiana aquifers – Mississippi River Alluvial Aquifer is the study region

Research Objectives

- Finding the determinants of irrigated acreage allocation in soybean cultivation
- Economic assessment of soil salinity in MRAA, Louisiana
- Develop conjunctive surface/ground water model to solve soil the salinity problem.

Methodology

1. Objective 1.

For our panel data we used fixed and random effect model. We modeled the parish specific irrigated acreage allocation A_{jit}, for soybean 'j' in parish 'i' in year't', which is defined as:

$\ln(AI_{jit}) = \tau_{i0} + \tau_1 p_{it} + \tau_2 q_{it} + \tau_3 r_{it} + \tau_4 s_{jit} + e_{jit}$

τ_{i0} is a constant, $\tau_1, \tau_2, \tau_3, \tau_4$ are the vectors for lag-corn yield, lag soybean yield, ratio of future corn price to soybean price, and soybean well.

Objective 2

Yield reduction due to salinity can be presented as $Y_r = 100 - b(EC_e - a)$

where *a* = the salinity threshold expressed in dS/m; *b* = the slope expressed in percent per dS/m; and *ECe* = the mean electrical conductivity of a saturated paste taken from the root zone.

We then assess the economic impact of salinity using input-output model.

Principal Findings and Significance

1. Objective 1:

	Soybean (Random Effects model)
Future price ratio (Corn: Soybean)	-1.1170023* (.5529829)
Lag corn yield	.00419162 (.0028018)
Lag Soybean yield	-.00373776 (.0044298)
Soybean well	0.006068*** (.0006282)
Cons	8.1572313*** (.3687296)
N	120
r2	
r2_a	

Note: Robust standard errors in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001

Irrigated area in this model is significantly and negatively affected by the corn to soybean future price ratio. Turning to the issue regarding the adverse effects of ground water extraction in the MRVA parishes, the number of wells are positively and significantly associated with the irrigated area expansion for soybean.

2. Objective 2:

Results from the IMPACT model

- Impact of salinity on cotton yield
- Impact of salinity on sugarcane yield
- Impact of salinity on grain yield
- Impact of salinity on all three crops in the region

Crops	Salinity tolerance threshold (dS/m)	Slope % per dS/m	Classification
Corn	1.7	12	MS
Cotton	7.7	5.2	T
Rice	3.0	12	S
Sorghum	6.8	16	MT
Soybeans	5	20	MT
Wheat	8.6	30	MT

Cotton

5%	Employment	Labor Income	Output
Direct	-27	-$2,729,790	-$5,377,903
Indirect	-10	-$443,514	-$1,249,216
Induced	-15	-$528,514	-$1,826,343
Total	-52	-$3,701,818	-$8,453,462

Grains (5% yield reduction)

	Employment	Labor Income	Output
Direct	-314	-$3,607,089	-$53,697,478
Indirect	-213	-$7,467,836	-$25,856,886
Induced	-53	-$1,852,584	-$6,402,792
Total	-580	-$12,927,509	-$85,957,155

Sugarcane (5% value reduction)

	Employment	Labor Income	Output
	-27	-$1,582,482	-$3,711,663
	-7	-$290,669	-$894,576
	-9	-$312,202	-$1,078,878
	-43	-$2,185,352	-$5,685,118

Grand total impact

5%	Employment	Labor Income	Output
Direct	-368	-$7,919,361	-$62,787,044
Indirect	-230	-$8,202,018	-$28,000,677
Induced	-77	-$2,693,300	-$9,308,013
Total	-675	-$18,814,679	-$100,095,734

Economic impacts of salinity could be substantial. If yield loss or area affected due to salinity is only 5%, employment will reduce by 368 people in the state, labor income will reduce by 7.9 million and total value of output loss will be $62.7 million. The aggregate economic impact (direct, indirect and induced impact combined) is almost the double than the direct impact.

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Satellite-Assisted Approach to Adaptive Water Quality Management of Lower Boeuf River

Basic Information

Title:	Satellite-Assisted Approach to Adaptive Water Quality Management of Lower Boeuf River
Project Number:	2016LA106B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	LA-06
Research Category:	Water Quality
Focus Category:	Models, Non Point Pollution, Water Quality
Descriptors:	None
Principal Investigators:	Zhi-Qiang Deng

Publications

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4. Deng, Z., 2017. Development of Watershed-Based Dynamic Total Maximum Daily Load for Dissolved Oxygen in Lower Bayou Macon, submitted to LWRRI/USGS in May 2016, 10 pages.
5. Roostaee, M. and Deng, Z. (2017). “Watershed Modeling for Evaluating Effects of DEM Resolution on Flow Simulation.” World Environmental & Water Resources Congress, May 21-25, 2017, Sacramento, California.

Problem and Research Objectives

Water quality improvement in Louisiana and in the Gulf of Mexico region is generally achieved through the implementation of Best Management Practices (BMPs). While extensive efforts have been made in the implementation of BMPs in Louisiana, there was no significant improving trend in water quality in terms of fully supporting the three primary designated uses in the past 15 years. This is particularly true for fish and wildlife propagation use. The most cited suspected causes of water quality impairment in Louisiana include low Dissolved Oxygen (DO), fecal coliform, mercury in fish tissue, turbidity and total dissolved solids. A basic hypothesis involved currently in the implementation of BMPs is that the pollution sources identified in the development of total maximum daily loads would not change with time. This is obviously not true particularly for nonpoint source pollution that caused impairment to the Lower Boeuf River. Fertilizers and pesticides applied to croplands may be transported to local river systems by rainfall runoff and irrigation drainage. Livestock manure contains nitrogen and phosphorus that may also contaminate streams. Land cover change could significantly increase loading of DO-consuming materials and thereby cause DO impairment in river systems. Since the land use and land cover change occurs over time, it is important to implement adaptive BMPs, calling for the adaptive management of water quality. A key barrier to the adaptive management of water quality is the lack of an effective approach to linking the land use and land cover change to the water quality change. This is a critical regional and state water quality management problem needing to be addressed.

The overall goal of this project was to develop a new approach, called satellite-assisted approach, to the adaptive implementation of BMPs and thereby the restoration of water quality and the sustainability of designated uses of Louisiana water bodies, addressing the critical regional and state water quality problem. The specific objectives of this project were (1) to detect land use and land cover change in the Boeuf River watershed using Landsat data, (2) to determine correlation between the land use and land cover change and water quality change in the Lower Boeuf River using stepwise regression analysis, and (3) to define adaptive BMPs for achieving designated use of the Boeuf River under changing land use and land cover using the US EPA watershed modeling tool HSPF.

Methodology

The proposed strategy was to test and demonstrate the new remote sensing-based management approach by the adaptive implementation of BMPs in the Lower Boeuf River (subsegment LA080901_00), as shown in Figure 1. The research methods involved (1) remote sensing-based detection of land use and land cover change, (2) linking remote sensing-based land use and land cover change to changes in individual water quality parameters, and (3) watershed modeling-based selection and adaptive implementation of BMPs. While this project focuses on the Lower Boeuf River, the remote sensing-assisted adaptive approach to BMP implementation can be easily extended to other watersheds in Louisiana and in the nation. Therefore, this project has broader implications for environmental restoration and sustainability in Louisiana and in the nation as well.

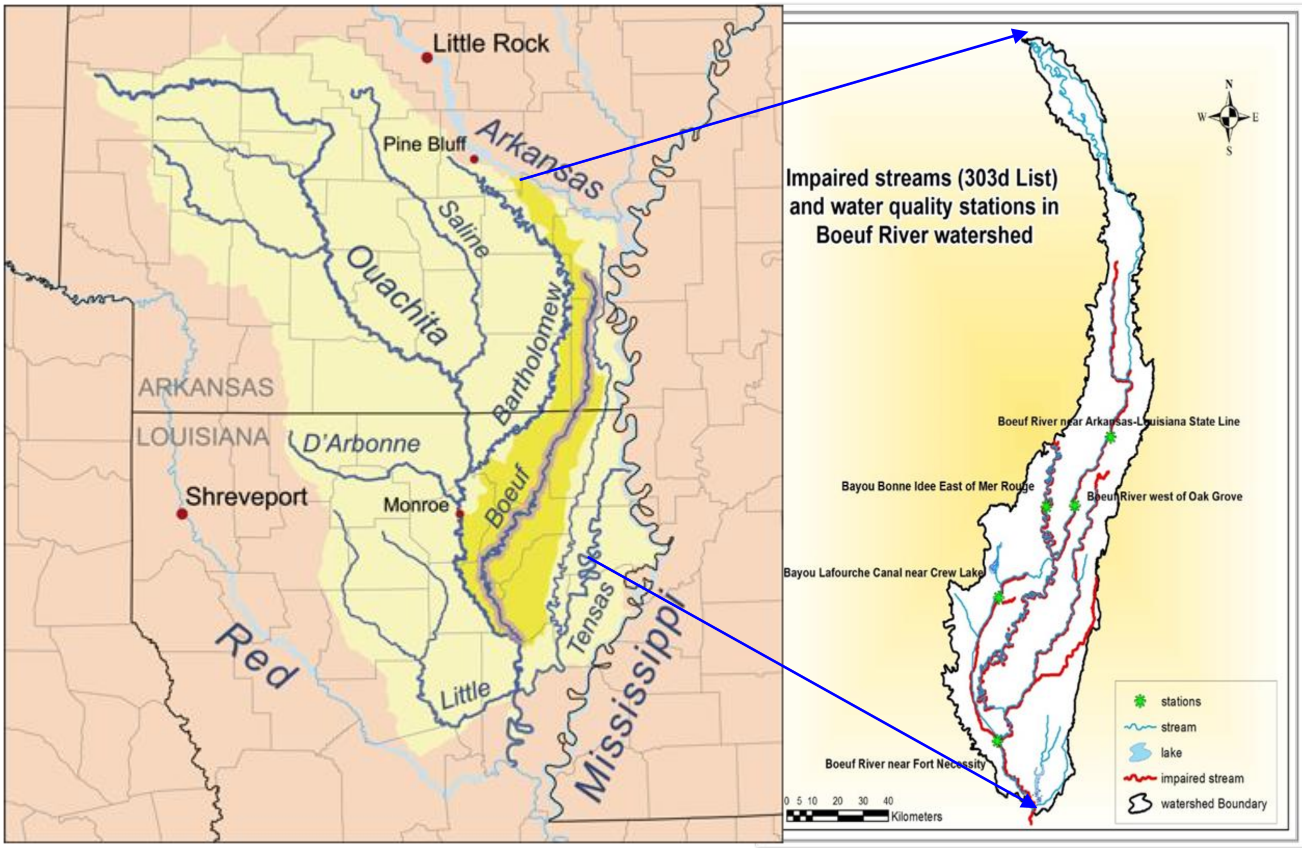

Figure 1. Study area map showing the impaired Boeuf River and tributaries.

PRINCIPAL FINDINGS AND SIGNIFICANCE

1. Remote Sensing-Based Detection of Land Use and Land Cover Change

(1) A remote sensing-based approach has been developed for detection of land use/land cover change in the Boeuf River watershed. Figure 2 below shows how the land use of major crops in Boeuf River Watershed changed from 2004 to 2016, demonstrating increasing trends in corn and soybean acreages. The practical significance of this approach is that satellite remote sensing data provide both spatial and temporal information needed to understand changes in land use and land cover necessary for modeling water quality impairment and developing adaptive BMPs to improve water quality in the watershed.

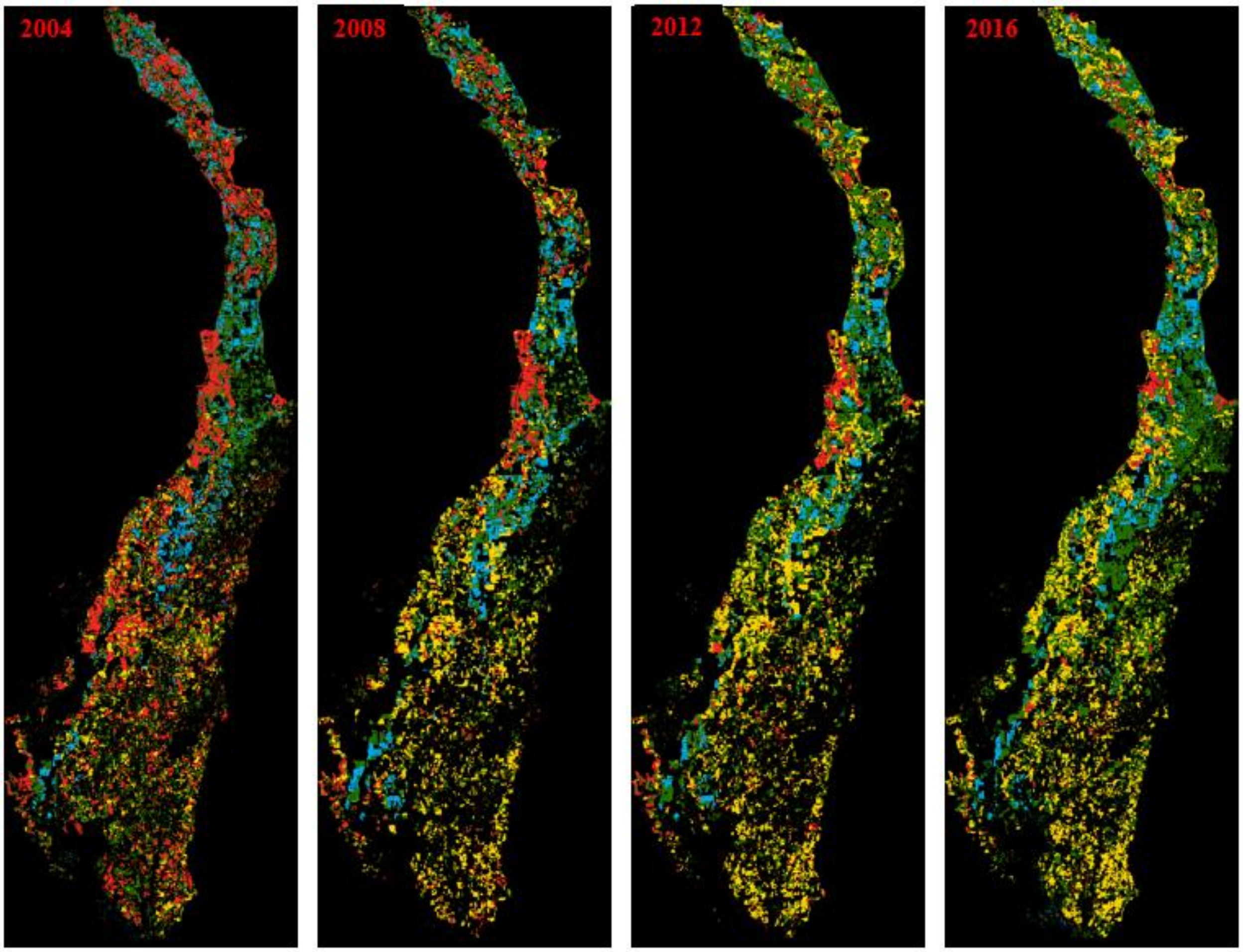

Figure 2. Remote sensing images showing changes in corn (yellow color), soybean (green color), cotton (red color) and rice (blue color) croplands in Boeuf River watershed from 2004 to 2016

(2) The remote sensing data were utilized to estimate acreages of major crops in different catchments of the Boeuf River Watershed, making it possible to identify the **critical catchments** which served as the source area of water body impairment and thereby providing suggestions for BMP implementation. Figures 3 (for Arkansas) and 4 (for Louisiana) show yearly changes in acreages of major crops in the Boeuf River Watershed, identified using the remote sensing data. It can be seen clearly from Figure 3 that the increasing corn acreage was accompanied by an increasing trend in the inorganic nitrogen concentration in the Boeuf River, indicating that the corn is the primary source of nitrogen input into waterbodies in the Boeuf River Watershed.

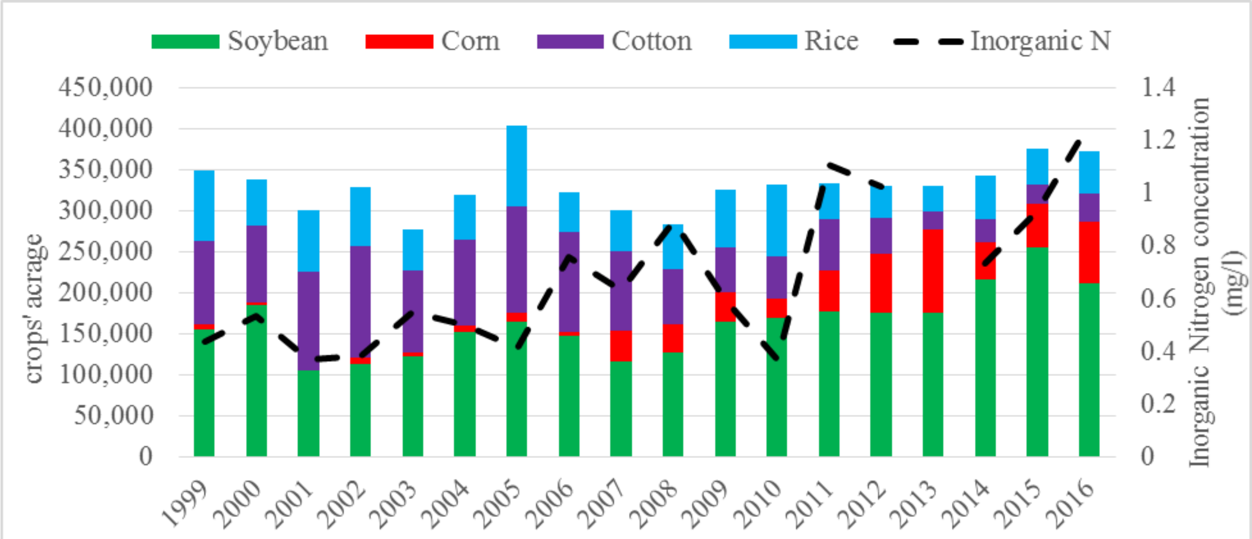

Figure 3. Variation in acreages of major crops from 1999 to 2016 in Upper Boeuf River Watershed (located in Arkansas)

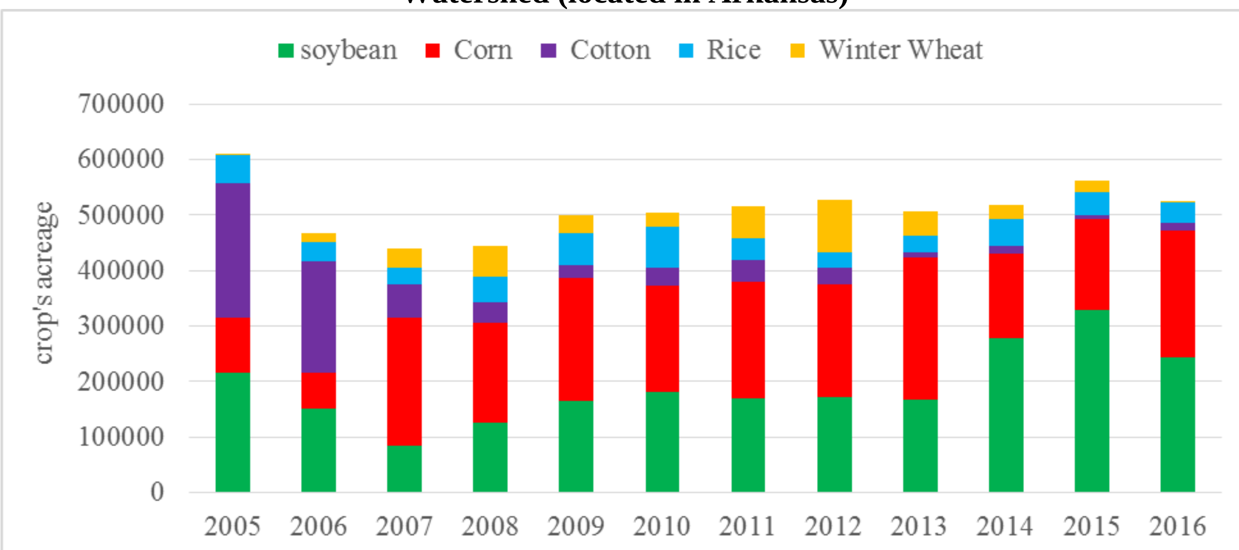

Figure 4. Variation in acreages of major crops from 1999 to 2016 in Lower Boeuf River Watershed (located in Louisiana)

2. Establishment of Relationship between Land Use and Land Cover Change and Water Quality Change

The establishment of the relationship between land use and land cover change and water quality change is a critical step towards the adaptive management of water quality. It was found that there was a strong correlation between the corn acreage and the nutrient level in Boeuf River, as shown in Figure 5 below, confirming the negative impact of increasing corn acreage on water quality in the Boeuf River watershed.

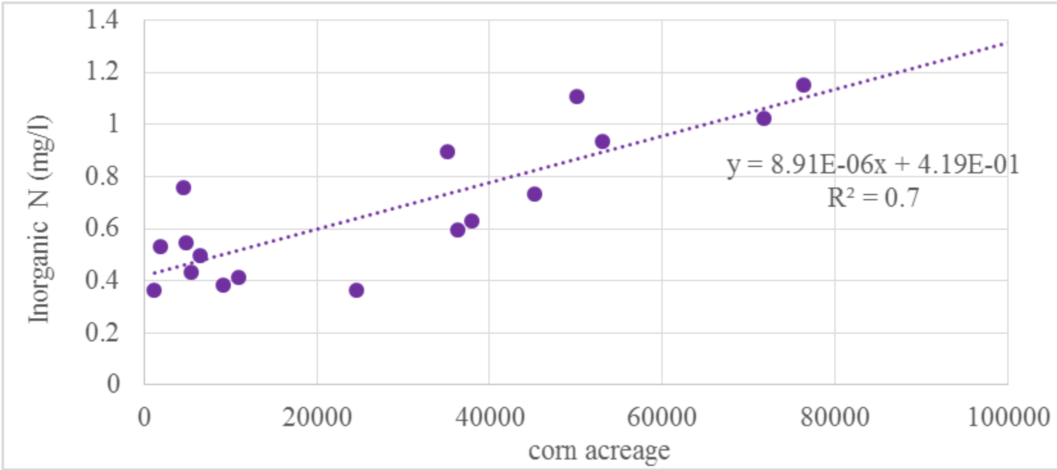

Figure 5. Correlation between Corn acreage and the inorganic nitrogen concentration in the Boeuf River Watershed

The significance of this finding is that the increasing level of nitrogen in the Boeuf River and tributaries are caused primarily by the increasing acreage of corn and associated fertilizer release into water bodies. Therefore, the implementation of BMPs should focus on corn fields in the Boeuf River watershed, identifying the critical source areas of water quality impairment in the Boeuf River watershed.

3. Watershed Modeling-Based Selection and Adaptive Implementation of BMPs

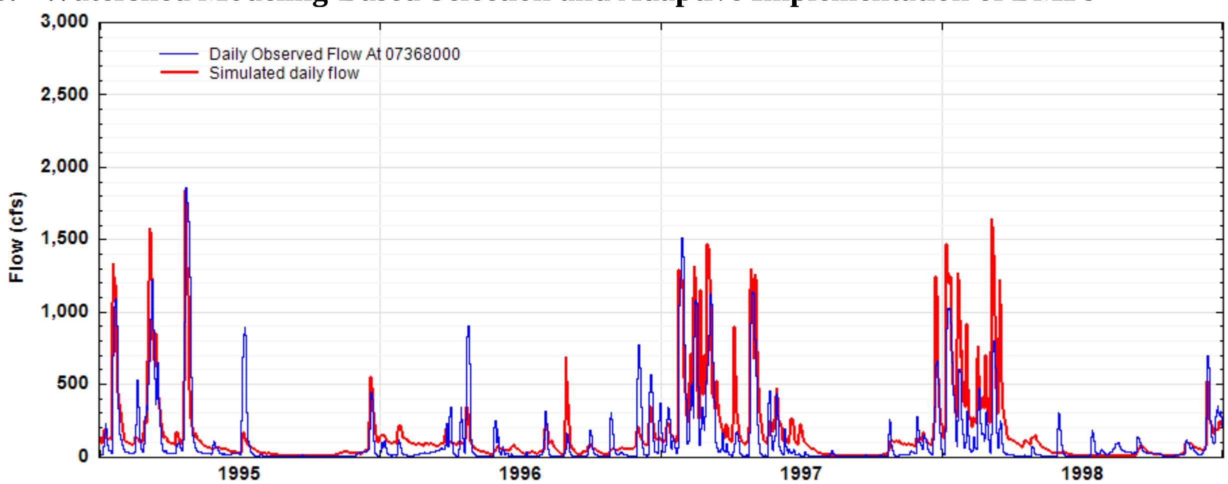

Figure 6. Results of flow calibration at Boeuf River near Girard

(1) A HSPF-based watershed model has been presented for computation of flow and nitrogen level in the Boeuf River watershed. Figure 6 indicates that the model-simulated flow fits observed one reasonably well (correlation coefficient = 0.81 and Nash-Sutcliffe efficiency = 0.58). The significance of this model is that it provides an effective and efficient modeling tool for governmental agencies like Louisiana Department of Environmental Quality to implement BMPs in the Boeuf River watershed and for restoration of impaired water bodies in the watershed.

(2) The validated HSPF model was utilized to simulate the variation of inorganic nitrogen level in the Boeuf River. Figure 7 shows inorganic nitrogen concentration variations in the Boeuf River at the AR/LA state line. The average concentrations of simulated and measured inorganic nitrogen were 0.46 and 0.42 mg/l, respectively, and the PBIAS value was -13.5%. It can be seen from Figure 7 that the watershed model is capable of simulating inorganic nitrogen concentrations in the Boeuf River even though the simulated concentrations were higher than the measured ones. The main reason for observing the nitrogen concentrations lower than simulated ones was attributed to the implementation of BMPs in the Lower Ouachita River Basin under Louisiana Conservation Reserve Enhancement Program (LA CREP I) while BMP effects were not included in the HSPF model simulated nitrogen concentrations shown in Figure 7. The significance of Figure 7 is that it clearly demonstrates the efficiency of BMPs in reducing nitrogen concentrations in the Boeuf River. It also confirms that the nitrogen concentrations in the Boeuf River would have been much higher than the current values if the BMPs were not implemented.

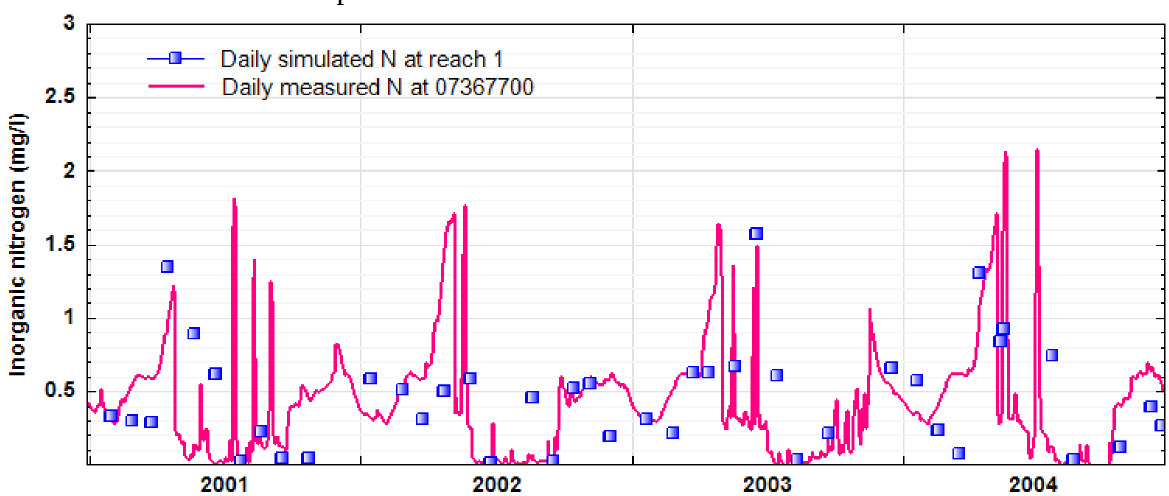

Figure 7. Measured and simulated inorganic nitrogen at Boeuf River at AR/LA state line.

Table 1. Adaptive BMP implementation for 3 corn acreage scenarios and model-simulated nitrogen concentrations under BMP implementation

Scenario #	Corn acreage (acre)	Increase in corn acreage (%)	Simulated Inorganic N concentration (mg/l)
1	70000	0	1.03
2	90000	28.6	1.21
3	110000	57.1	1.39

(3) The validated HSPF model was further employed to test the performance of the model in BMP (particularly riparian buffers) modeling for the reduction of inorganic nitrogen level in the Boeuf River. To that end, three BMP implementation scenarios, as defined in Table 1, were considered based on the relationship (Figure 5) between the corn acreage and inorganic N concentration. In these scenarios the average of corn acreages in last 5 years was considered as the base scenario and the effects of increment of 20,000 acres in corn acreage on instream nitrogen concentrations were evaluated. It was assumed that total

cropland acreage would remain unchanged in future and only crop types would change. Figure 8 shows model simulated inorganic nitrogen concentration variations against the data observed in the Boeuf River at the AR/LA state line for the period from 11/2008 to 09/2009 in which observed data were available, demonstrating the efficacy of the validated HSPF model in simulating BMP implementation.

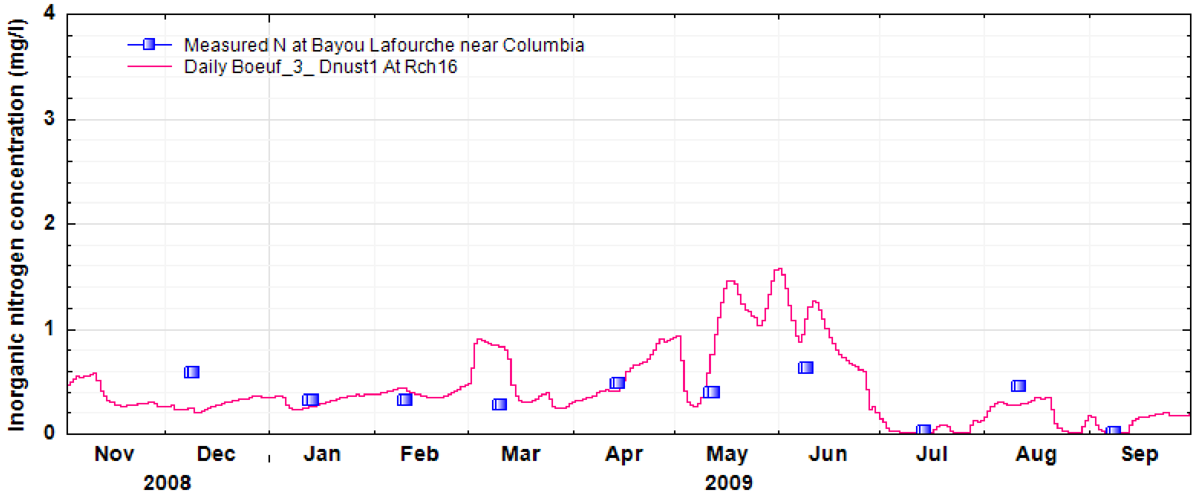

Figure 8. Measured and simulated inorganic nitrogen at Bayou Lafourche near Columbia after application of BMPs in Lower Boeuf watershed based on LA CREP I.

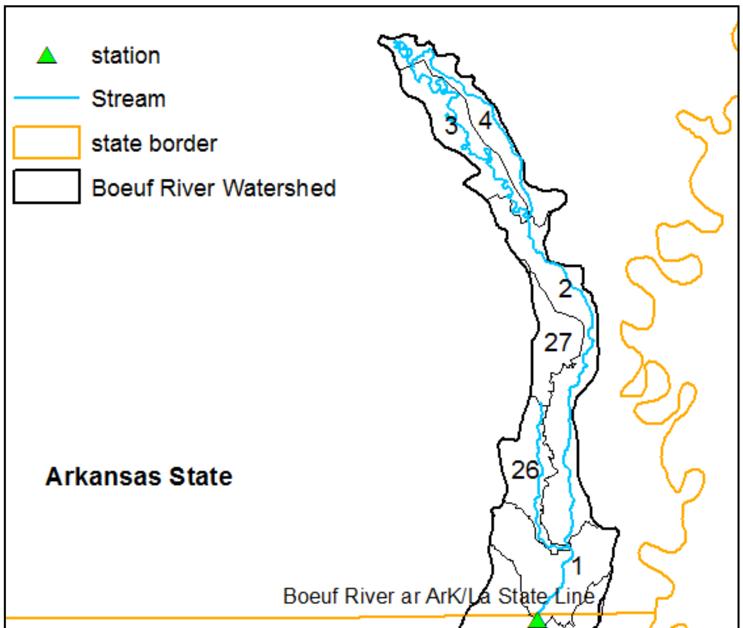

Figure 9. Subwatersheds in Upper Boeuf Watershed.

(4) The tested HSPF model was finally applied to simulate the adaptive implementation of BMPs (particularly riparian buffers) for the reduction of inorganic nitrogen level in the Boeuf River. Since riparian buffers have been successfully implemented in Lower Boeuf River watershed as BMPs for N reduction, they were considered as the main choice of BMPs for the Upper Boeuf River watershed. Riparian buffers were first considered for the subwatersheds with the highest nitrogen production (subwatersheds 1, 2 and 26 in Figure 9). While the implementation of riparian buffers in the four subwatersheds resulted in a significant reduction in nitrogen concentrations but the nitrogen concentrations in the river were still higher than the background level of N (0.24 mg/L) in the river. In order to reduce the nitrogen concentration to the background level of 0.24 mg/L buffer zones were also added to other subwatersheds. Figure 10 shows the effects of implementing riparian buffers in the Upper

Boeuf River subwatersheds for the three scenarios defined in Table 1. These buffers are supposed to capture sediment and nutrient from 90% of agriculture and urban areas in all subwatersheds in the Upper Boeuf River watershed. The results in Figure 10 clearly indicates the efficiency and benefit of BMP implementation in the Boeuf River watershed.

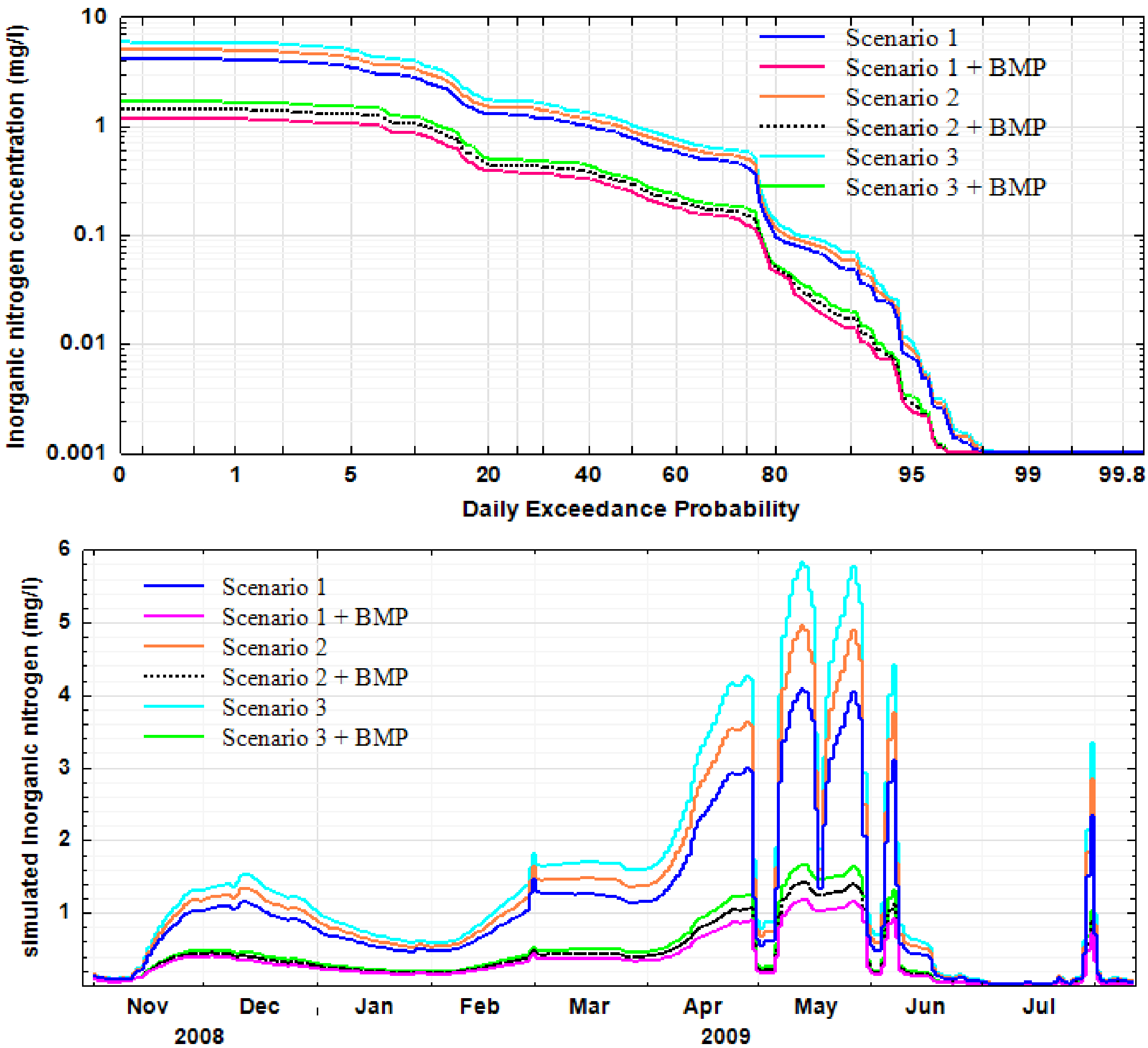

Figure 10. Daily exceedance probability (upper panel) and time series of simulated inorganic N concentration (lower panel) for various scenarios with and without BMP (riparian buffer) application.

Table 2 summarizes the impact of increasing corn acreage on inorganic N concentrations in the Upper Boeuf River watershed under Scenarios 1 - 3, and thereby on water quality of downstream river reaches. The table indicates that the increase in corn acreage in the Upper Boeuf River not only elevates the concentration of inorganic N at station 07367700 (Boeuf River at AR/LA state line) but also has negative impact on the water quality of downstream reaches

(Bayou Lafourche near Columbia station 07369000). The table also demonstrates that the implementation of BMPs (riparian buffers) could effectively improve water quality. However, these buffers alone are not sufficient for reducing inorganic N level in the Boeuf River watershed to the background level. Other edge-of-field BMPs such as filter strips or in-field conservation practices (such as or fertilizer rate optimization/reduction) are needed to reach the water quality standard level for inorganic N if corn acreage keeps growing as projected in the scenarios. In addition to riparian buffers, filter strips with the nitrate removal efficiency of 21% (removal efficiency was determined based on the range recommended in HSPF model) were also added to agricultural areas in scenario 1. As a result, the mean inorganic N concentration, simulated with HSPF model, dropped to 0.27 mg/L which was very close to the historic water quality condition or the background N level of 0.24 mg/L.

The significance of the scenario-based results is that the results provide scientific basis for adaptive implementation of BMPs in future if corn acreage further increases, preventing waterbody impairment and achieving the sustainability of designated uses of water bodies under changing land use and land cover.

Table 2. Mean simulated concentration of inorganic N at stations 07367700 and 07369000 for various scenarios with and without BMP application.

Scenario #	Mean simulated inorganic N concentration (mg/l)			
	Before BMP	After BMP	Before BMP	After BMP
	at station 07367700 Boeuf River at AR/LA State line		at station 07369000 Bayou Lafourche near Columbia	
1	1.02	0.31	0.68	0.3
2	1.21	0.37	0.79	0.33
3	1.4	0.42	0.9	0.36

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	1	0	0	0	1
Masters	0	0	0	0	0
Ph.D.	7	0	0	0	7
Post-Doc.	2	0	0	0	2
Total	10	0	0	0	10

Notable Awards and Achievements

The LWRRI initiated a Louisiana Well Log Portal (https://sites.google.com/site/louisianawelllogportal/) in 2014. Up to date, more than 66,000 electric logs and drillers logs have been added to the Portal. This academic year more than 240 CEE undergraduate students were trained to analyze electrical logs and drillers' logs through course projects. Students learnt documenting well log data into Excel spreadsheets, making Google Earth kml files, and displacing well log data to Google Earth. The students' data were eventually deposited to the Portal after quality control. State agencies, the public, and private sectors have been using the Portal to understand Louisiana's geology and groundwater resources. The Portal has been visited by more than 4,600 times and more than 10 countries.

PI Deng's project "Louisiana Watershed Education Initiative for Environmental Sustainability", funded previously by the Louisiana Water Resources Research Institute, was selected by the National Institutes For Water Resources to feature this particular project in the 2017 report of the national network.

The LWRRI co-organized the 10th Annual Louisiana Groundwater, Surface Water and Water Resource Symposia, Louisiana State University, Baton Rouge, Louisiana, March 24-25, 2016

Publications from Prior Years

1. 2016LA-ADMIN ("") - Articles in Refereed Scientific Journals - Pham, H.V., and F. T.-C. Tsai (2017), Modeling complex aquifer systems: a case study in Baton Rouge, Louisiana (USA). Hydrogeology Journal. doi:10.1007/s10040-016-1532-6
2. 2016LA-ADMIN ("") - Articles in Refereed Scientific Journals - Mani, A., and F. T.-C. Tsai (2017), Ensemble averaging methods for quantifying uncertainty sources in modeling climate change impact on runoff projection. Journal of Hydrologic Engineering 22(4). doi:10.1061/(ASCE)HE.1943-5584.0001487
3. 2016LA-ADMIN ("") - Articles in Refereed Scientific Journals - Mani, A., F. T.-C. Tsai, S.-C. Kao, B. S. Naz, M. Ashfaq, and D. Rastogi. (2016). Conjunctive management of surface and groundwater resources under projected future climate change scenarios. Journal of Hydrology, 540, 397-411. doi: 10.1016/j.jhydrol.2016.06.021
4. 2016LA-ADMIN ("") - Other Publications - Tsai, F. T.-C., and E. Beigi, Bayesian Model Averaging for Uncertainty Analysis on Hydrologic Projections under Future Climate Change, World Environmental & Water Resources Congress 2016, West Palm Beach, FL, May 22-26, 2016
5. 2016LA-ADMIN ("") - Other Publications - Tsai, F. T.-C., and E. Beigi, Bayesian Model Averaging for Uncertainty Analysis on Hydrologic Projections under Future Climate Change, World Environmental & Water Resources Congress 2016, West Palm Beach, FL, May 22-26, 2016
6. 2016LA-ADMIN ("") - Other Publications - Tsai, F. T.-C. Tsai and H. V. Pham, Data-Driven Groundwater Model Development: A Case Study in Baton Rouge, Louisiana, 2016 AGU Fall Meeting San Francisco, CA, USA, 12-16 December 2016
7. 2016LA-ADMIN ("") - Other Publications - Pham, H.V. and F. T.-C. Tsai, High-resolution Groundwater Model Development using Supercomputer, Data Flow: Grand Challenges in Water Systems Modeling, Data Management, and Integration, May 9-10, 2016, Baton Rouge, Louisiana
8. 2016LA-ADMIN ("") - Other Publications - Yin, J. and F. T.-C. Tsai, Saltwater Intrusion Mitigation Strategies for Baton Rouge Multi-Aquifer System, Southeast Louisiana, 2016 UCOWR/NIWR Conference, Pensacola, Florida, June 21-23, 2016
9. 2016LA-ADMIN ("") - Other Publications - Tsai, F. T.-C., Utilizing Big Geological Data for Groundwater Management, Data Flow: Grand Challenges in Water Systems Modeling, Data Management, and Integration, May 9-10, 2016, Baton Rouge, Louisiana
10. 2016LA-ADMIN ("") - Dissertations - Mani, Amir, 2016. “Conjunctive Management of Water Resources under Climate Change Projection Uncertainty”, Ph.D. Dissertation, Louisiana State University, Baton Rouge. http://digitalcommons.lsu.edu/gradschool_dissertations/3058/